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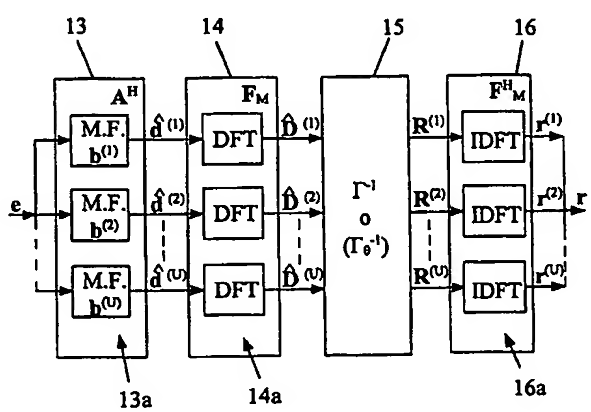
(54) Title: LOW COMPUTATIONAL COMPLEXITY JOINT DETECTION FOR HYBRID TD-CDMA SYSTEMS



(57) **Abstract:** A method for equalization of a signal propagating in a hybrid TD-CDMA system where U users transmit simultaneously with a receiver having a given CDMA signature sequence for generating a detected symbol which estimates a transmitted symbol comprises the steps of performing the DTF of each vector $\hat{d}$ output from the "matched filter" bank to find U vectors $\hat{D}$ to which to apply a transformation represented by a matrix Γ^{-1} (for ZF-BLE) or a matrix $[\sigma^2 MI_M+\Gamma]^{-1}$ (for MMSE-BLE) to find U vectors $R^{(1)},...,R^{(U)}$ und perform the IDFT for each vector $R^{(1)}$,...,R?(u)¿ to find U vectors to be used as estimation vectors $r^{(1)},...;r^{(u)}$. In ccordance with the method an equalizser comprises a matched filter bank (13) at the input of which is applied the received signal. The matched filter bank has in output U vectors $\hat{d}$ which are sent to a plurality of DTF calculation blocks (14) to find at the output of each block a corresponding vector $\hat{D}$. Transformation means (15) perform on the vectors D the transformation represented by a matrix Γ^{-1} if a ZF-BLE equalization is wanted or a matrix $[\sigma^2 NI_n +g(G)]_{-1}$ if an MMSE-BLE equalization is wanted so as to give at thier output corresponding U vectors $R^{(i)},...,R^{(u)}$. Each IDFT calculation block (16) receives one of the vectors $R^{(i)},...,R^{(u)}$ to supply at output a corresponding vector r. These vectors r are the sought estimation vectors $r^{(i)},...,r^{(u)}$.

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'Low computational complexity joint detection for hybrid TD-CDMA systems'

The present invention relates to a method and an equalizer for performance of joint detection in hybrid TD-CDMA systems.

In TD-CDMA systems several users transmit and receive while sharing the same time slot and frequency band. With every user are therefore associated one or more recognition codes (operation termed 'spreading') so as to permit reconstruction of the transmitted information.

Even if the codes are generated orthogonal to each other, transmission in dispersive media creates correlation between the messages of different users so that in addition to intersymbol interference (ISI) there is multiple access interference (MAI) in reception. The simultaneous presence of ISI and MAI makes the equalizers normally used in the single user case inefficient computationally and in terms of performance. On the other hand the limited number of simultaneously active users suggests solutions applying so-called 'multiuser detection' so as to exploit the knowledge of the codes and pulsed answers of the transmission means.

Known joint detector equalizers nearly optimal for TD-CDMA systems then apply the "Zero-Forcing" (ZF) and "Minimum Mean Square Error" (MMSE) estimation rules and exploit the information packet organization so as to be able to simultaneously process the information of an entire data block per user (ZF-BLE and MMSE-BLE).

If M indicates the product of the number U of simultaneously active users and the number N of symbols per data block these known equalizers have $O(M^3)$ computational complexity. This complexity is very high even with a small number of users because of the necessity of reversing or factorizing matrices of considerable size by the Cholesky method.

The general purpose of the present invention is to remedy the above shortcomings by making available a method for signal equalization in TD-CDMA systems and an equalizer applying this method which would have reduced complexity as compared with the prior art.

In view of this purpose it was sought to provide in accordance with the present invention a method for equalization of a signal propagating in a hybrid TD-CDMA system where U users transmit simultaneously with a receiver having a given CDMA signature sequence for generating a detected symbol which estimates a transmitted symbol with the received signal being sent to a matched filter bank at the output of which are obtained U vectors $\hat{\mathbf{d}}^{(i)}=[\hat{d}^{(i)}_1,\ldots,\hat{d}^{(i)}_N]^T$, with $i=1,\ldots,U$ which are processed to find the estimation vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$ of the transmitted symbol and comprising the steps of performing the DTF on N points of each vector $\hat{\mathbf{d}}^{(i)}$ to find U vectors $\hat{\mathbf{D}}^{(i)}$ made up of N elements, applying to $\hat{\mathbf{D}}=[\hat{\mathbf{D}}^{(1)},\hat{\mathbf{D}}^{(2)},\ldots,\hat{\mathbf{D}}^{(U)}]$ a transformation represented by a matrix Γ^{-1} if a ZF-BLE is wanted or by a matrix $[\sigma^2 N I_M+\Gamma]^{-1}$ if an MMSE-BLE is wanted to find U vectors $\mathbf{R}^{(1)},\ldots,\mathbf{R}^{(U)}$ of size N and perform IDFT on N points for each vector $\mathbf{R}^{(1)},\ldots,\mathbf{R}^{(U)}$ to find U vectors made

up of N elements and use these vectors as estimation vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$.

Still in accordance with the present invention it was also sought to provide an equalizer for equalization of a signal propagating in a hybrid TD-CDMA system where U users transmit simultaneously in a receiver having a given CDMA signature sequence for generating a detected symbol which estimates a transmitted symbol with the equalizer comprising a matched filter bank at the input of which is applied the received signal with the matched filter bank having in output U vectors $\hat{\mathbf{d}}^{(i)}=[\hat{d}^{(i)}_1,\ldots,\hat{d}^{(i)}_N]^T$, con $i=1,\ldots,U$ which are sent to processing means at whose output are obtained the sought estimation vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$ of the transmitted symbol characterized in that the processing means comprise a plurality of DTF calculation blocks on N points with there being sent to each block one of the vectors $\hat{\mathbf{d}}^{(i)}$ to find at the output of each block a corresponding vector $\hat{\mathbf{D}}^{(i)}$; transformation means which receive the vectors $\hat{\mathbf{D}}^{(i)}$ and which perform the transformation represented by a matrix Γ^{-1} if a ZF-BLE equalization is wanted or by a matrix $[\sigma^2 N I_M + \Gamma]^{-1}$ if an MMSE-BLE is wanted so as to give at their output corresponding U vectors $\mathbf{R}^{(1)},..,\mathbf{R}^{(U)}$ and a plurality of IDFT calculation blocks on N points with there being sent to each block one of the vectors $\mathbf{R}^{(1)},..,\mathbf{R}^{(U)}$ to find at the output of each block a corresponding vector $\mathbf{r}$ made up of N elements with each vector $\mathbf{r}$ made up of N elements with said vectors $\mathbf{r}$ being the above mentioned sought estimation vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$.

To clarify the explanation of the innovative principles of the present invention and its advantages compared with the prior art there is described below with the aid of the annexed drawings a possible embodiment thereof by way of non-limiting example applying said principles. In the drawings:

- FIG 1 shows a model of the base band equivalent of the up-link connection in a TD-CDMA system, and
- FIG 2 shows a block diagram of an equalizer ZF-BLE (or MMSE-BLE) with reduced complexity provided in accordance with the principles of the present invention.

With reference to the figures, FIG 1 shows the block diagram of the base band equivalent of an up-link connection in a TD-CDMA system.

A number U of users are simultaneously active and the generic user u transmits a sequence of symbols represented by the vector $\mathbf{d}^{(u)}$.

Each symbol is associated with the code sequence $\mathbf{c}^{(u)}$ of Q length and the uth user information, now expressed on times which are a multiple of $Tc=Ts/Q$, is processed by the channel with pulsed response $\mathbf{g}^{(u)}$ made up of L samples.

For the sake of convenience it is best to express with the filter $\mathbf{b}^{(u)}=\mathbf{c}^{(u)}*\mathbf{g}^{(u)}$ the combined effect of spreading and transmission means. With the symbols simultaneously processed organized in a single vector $\mathbf{d}=[\mathbf{d}^{(1)};\ldots;\mathbf{d}^{(U)}]$ and added noise denoted by $\mathbf{n}$ the information vector at the receiver input satisfies the linear relationship $\mathbf{e}=\mathbf{A}\mathbf{d}+\mathbf{n}$, where the matrix $\mathbf{A}$ is defined as:

$$
\mathbf{A}=\left|\begin{array}{cccc|c|cccc}
b^{(1)}_1 & 0 & \cdots & 0 & & b^{(U)}_1 & 0 & \cdots & 0 \\
b^{(1)}_2 & 0 & \cdots & 0 & & b^{(U)}_2 & 0 & \cdots & 0 \\
\vdots & \vdots & & \vdots & & \vdots & \vdots & & \vdots \\
b^{(1)}_{Q+1} & b^{(1)}_1 & \cdots & 0 & \cdots & b^{(U)}_{Q+1} & b^{(U)}_1 & \cdots & 0 \\
\vdots & & & & & \vdots & & & \\
b^{(1)}_{Q+L-1} & \vdots & & \vdots & \vdots & b^{(U)}_{Q+L-1} & \vdots & & \vdots \\
\vdots & & \vdots & & & \vdots & & \vdots & \\
0 & & \cdots & 0 & \vdots & 0 & & \cdots & 0 \\
\vdots & & & b^{(1)}_1 & & \vdots & & & b^{(U)}_1 \\
 & b^{(1)}_{Q+L-1} & & \vdots & \cdots & & b^{(U)}_{Q+L-1} & & \vdots \\
 & \vdots & & & & & & \vdots & \\
0 & 0 & \cdots & b^{(1)}_{Q+L-2} & & 0 & 0 & \cdots & b^{(U)}_{Q+L-2} \\
0 & 0 & \cdots & b^{(1)}_{Q+L-1} & & 0 & 0 & \cdots & b^{(U)}_{Q+L-1}
\end{array}\right|
$$

For the sake of simplicity the present invention is described below with reference to the case of independent symbols with unitary variance and white noise σ^2. This case is not particularly restrictive. With the instructions given below application to the different possible cases will be clear.

With **r** indicating the vector before estimation of data **d** the rule ZF gives:

$$\mathbf{r}=(\mathbf{A}^H\mathbf{A})^{-1}\mathbf{A}^H\mathbf{e}$$

while the rule MMSE gives at output:

$$\mathbf{r}=(\mathbf{A}^H\mathbf{A}+\sigma^2\mathbf{I}_M)^{-1}\mathbf{A}^H\mathbf{e},$$

where $\mathbf{I}_M$ is the identity matrix M x M.

The process in accordance with the present invention which gives a substantial complexity reduction and the innovative equalizer receiver which applies this process are described below.

Take the Hermitian matrix $\mathbf{A}^H\mathbf{A}$ present in both the equalization diagrams and partition in U^2 N x N band Toeplitz sub-matrices of the form:

$$\overline{\mathbf{T}_{i,j}} = \begin{vmatrix} t_0 & t_{-1} & \cdots & t_{-m} & \cdots & 0 \\ t_1 & t_0 & \cdots & t_{-m+1} & \ddots & \vdots \\ \vdots & & \ddots & & & t_{-m} \\ t_m & t_{m-1} & & & & \vdots \\ \vdots & \ddots & & & t_0 & t_{-1} \\ 0 & \cdots & t_m & \cdots & t_1 & t_0 \end{vmatrix} \quad i,j=1,\ldots,U$$

where the order m is linked to the spreading factor and to the pulsed response length of the channel by the relationship $m=[(L-1)/Q]$.

When m<<N any sub-matrix can be approximated with the asymptotically equivalent circular matrix $\mathbf{T}_{i,j}$ constructed as described e.g. in *R.M. Gray, 'On the Asymptotic Eigenvalue Distribution of Toeplitz Matrices'* in IEEE Trans. Info Theory, November 1972, Vol. 18, n°6, pages 725-730.

If the condition m<<N does not occur, e.g. because L is too big, known 'training sequence' symbols can be added to the ends of the data packet of each user until the condition is attained.

Indicating with $[t_0,t_1,\ldots,t_{-m+1},t_{-m}]^T$ the first column of the matrix $\mathbf{T}_{i,j}$, the diagonal matrix N x N can be defined as follows:

$$\Gamma_{i,j}=N\mathrm{diag}\{\mathrm{DFT}[t_0,t_1,\ldots,t_{-m+1},t_{-m}]\}, \qquad i,j=1,\ldots,U$$

With the matrix operating the DFT on N samples denoted by $\mathbf{P}_N$ the circular matrix $\mathbf{T}_{i,j}$ enjoys the factorizing properties:

$$\mathbf{T}_{i,j}=1/N^2\mathbf{P}^H{}_N\Gamma_{i,j}\mathbf{P}_N, \qquad i,j=1,\dots,U$$

As the factorization can be applied to each of the U^2 sub-matrices of $\mathbf{A}^H\mathbf{A}$ it is best to introduce the matrix M x M:

$$\mathbf{F}_M = \begin{vmatrix} \mathbf{P}_N & 0 & \dots & 0 \\ 0 & \mathbf{P}_N & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \dots & \mathbf{P}_N \end{vmatrix}$$

which provides U DFT on N samples and expresses the matrix $\mathbf{A}^H\mathbf{A}$ in factorized form:

$$\mathbf{A}^H\mathbf{A} = 1/N^2\mathbf{F}^H{}_M \begin{vmatrix} \Gamma_{1,1} & \Gamma_{1,2} & \dots & \Gamma_{1,U} \\ \Gamma_{2,1} & \Gamma_{2,2} & \dots & \Gamma_{2,U} \\ \dots & & \ddots & \vdots \\ \Gamma_{U,1} & \Gamma_{U,2} & \dots & \Gamma_{U,U} \end{vmatrix} \mathbf{F}_M = 1/N^2\mathbf{F}^H{}_M\Gamma\mathbf{F}_M$$

In addition, exploiting the orthogonality property of the matrix $\mathbf{P}_N$, we find $\mathbf{F}_M{}^{-1}=1/N\ \mathbf{F}^H{}_M$.

We can therefore write:

$$(\mathbf{A}^H\mathbf{A})^{-1}= \mathbf{F}^H{}_M\Gamma^{-1}\mathbf{F}_M$$

The matrix Γ is a U x U matrix with matrix elements and each sub-matrix $\Gamma_{i,j}$ making it up is diagonal. Therefore the operations can be conducted element by element with a complexity O(N). Exploiting this property the matrix Γ^{-1} and hence $(\mathbf{A}^H\mathbf{A})^{-1}$ can be calculated with a complexity $O(NU^3)= O(MU^2)$ instead of $O(M^3)$ in the general case. Since M>>U, the calculation complexity is considerably reduced. At this point, to find an efficient equalizer applying the 'Zero-Forcing' (ZF-BLE) rule it suffices to substitute the above calculated:

$$(\mathbf{A}^H\mathbf{A})^{-1}= \mathbf{F}^H{}_M\Gamma^{-1}\mathbf{F}_M$$

in the previously defined expression of the estimate $\mathbf{r}=(\mathbf{A}^H\mathbf{A})^{-1}\mathbf{A}^H\mathbf{e}$ to find the vector $\mathbf{r}$ as:

$$\mathbf{r}= (\mathbf{F}^H{}_M\Gamma^{-1}\mathbf{F}_M)\ \mathbf{A}^H\mathbf{e}$$

But to find an efficient equalizer applying the 'Minimum Mean Square Error' (MMSE-BLE) rule it suffices to substitute the above calculated:

$$(\mathbf{A}^H\mathbf{A})^{-1}= \mathbf{F}^H{}_M\Gamma^{-1}\mathbf{F}_M$$

in the previously defined expression of the estimate $\mathbf{r}=(\mathbf{A}^H\mathbf{A}+\sigma^2\mathbf{I}_M)^{-1}\mathbf{A}^H\mathbf{e}$. The vector $\mathbf{r}$ will be:

$$\mathbf{r} = \mathbf{F}^H{}_M[\sigma^2N\mathbf{I}_M +\Gamma]^{-1}\mathbf{F}_M\mathbf{A}^H\mathbf{e}$$

The matrix $\Gamma_\theta=\sigma^2N\mathbf{I}_M +\Gamma$ can still be partitioned in U^2 diagonal sub-matrices, therefore the calculation of the reverse matrix still requires $O(MU^2)$ operations.

The block diagram of a reduced-complexity receiver provided in accordance with the present invention is shown in FIG 2. As may be seen in this FIG, the information vector $\mathbf{e}=[e_1,e_2,\ldots e_{QN+L-1}]^T$ which reaches the receiver input is applied to a block 13 which performs the operation $\mathbf{A}^H$. Q è is the 'spreading factor', L the number of coefficients of the transmission channel base band equivalent of the and N the number of symbols of each data block. This block 13 is the 'matched filter' bank whose output is to be sent to processing means for estimation. Block 13 comprises a plurality of sub-blocks 13a which apply the matched filter on the vectors $\mathbf{b}^{(1)}, \mathbf{b}^{(2)},\ldots,\mathbf{b}^{(U)}$ as set forth above.

At the output of the matched filter bank there are U vectors of size N denoted by $\hat{d}^{(i)}=[\hat{d}^{(i)}{}_1,\ldots,\hat{d}^{(i)}{}_N]^T$, $i=1,\ldots,U$. In accordance with the present invention the output of each block 13a is applied to a respective block

14a which performs the U DFT on N samples. All the blocks 14a therefore provide a block 14 which calculates the $\mathbf{F}_M$. There are thus obtained U vectors of N symbols which are denoted by $\hat{\mathbf{D}}^{(I)}$. All the outputs from the blocks 14a, i.e. the NU symbols represented by the vector written as $\hat{\mathbf{D}} = [\hat{\mathbf{D}}^{(1)}, \hat{\mathbf{D}}^{(2)}, \ldots, \hat{\mathbf{D}}^{(U)}]$ become the input of the calculation block 15 which performs the transformation represented by the matrix Γ^{-1} (for the equalizer ZF-BLE) or the matrix $[\sigma^2 N \mathbf{I}_M + \Gamma]^{-1}$ (for the equalizer MMSE-BLE). The block 15 has U outputs $\mathbf{R}^{(1)}, \ldots, \mathbf{R}^{(U)}$ of size N vectors. Each output is sent to a block 16a which performs an IDFT, again on N points. The complex 16 of the blocks 16a therefore performs the $\mathbf{F}^H_M$. The outputs of the blocks 16a are the sought $\mathbf{r}^{(1)}, \ldots, \mathbf{r}^{(U)}$ which make up the estimation vector $\mathbf{r}$ as defined above.

It is now clear that the preset purposes have been achieved, simplifying the receiver structure using the circulant approximation as described above and thus going from a higher complexity $O(M^3)$ to a significantly lower complexity $O(MU^2)$. In other words, instead of operating on an entire sequence of UN symbols at the output of the known matched filter bank, in accordance with the present invention one operates on U sub-blocks of N elements by DFT and IDFT operations.

Naturally the above description of an embodiment applying the innovative principles of the present invention is given by way of non-limiting example of said principles within the scope of the exclusive right claimed here.

CLAIMS

1. Method for equalization of a signal propagating in a hybrid TD-CDMA system where U users transmit simultaneously with a receiver having a given CDMA signature sequence for generating a detected symbol which estimates a transmitted symbol with the received signal being sent to a matched filter bank at the output of which are obtained U vectors $\hat{\mathbf{d}}^{(i)}=[\hat{d}^{(i)}_1,\dots,\hat{d}^{(i)}_N]^T$, with i=1,…,U which are processed to find the estimation vectors $\mathbf{r}^{(1)},\dots,\mathbf{r}^{(U)}$ of the transmitted symbol and comprising the steps of:
- performing the DTF on N points of each vector $\hat{\mathbf{d}}^{(i)}$ to find U vectors $\hat{\mathbf{D}}^{(i)}$ made up of N elements,
- applying to $\hat{\mathbf{D}}=[\hat{\mathbf{D}}^{(1)},\hat{\mathbf{D}}^{(2)},\dots,\hat{\mathbf{D}}^{(U)}]$ a transformation represented by a matrix Γ^{-1} if a ZF-BLE is wanted or by a matrix $[\sigma^2 N I_M+\Gamma]^{-1}$ if an MMSE-BLE is wanted to find U vectors $\mathbf{R}^{(1)},\dots,\mathbf{R}^{(U)}$ of size N, and
- performing the IDFT on N points for each vector $\mathbf{R}^{(1)},\dots,\mathbf{R}^{(U)}$ to find U vectors made up of N elements and using these vectors as estimation vectors $\mathbf{r}^{(1)},\dots,\mathbf{r}^{(U)}$.

2. Equalizer for equalization of a signal propagating in a hybrid TD-CDMA system where U users transmit simultaneously in a receiver having a given CDMA signature sequence for generating a detected symbol which estimates a transmitted symbol with the equalizer comprising a matched filter bank at the input of which is applied the received signal with the matched filter bank having in output U vectors $\hat{\mathbf{d}}^{(i)}=[\hat{d}^{(i)}_1,\dots,\hat{d}^{(i)}_N]^T$, with i=1,…,U which are sent to processing means at whose output are obtained the sought estimation

vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$ of the transmitted symbol characterized in that the processing means comprise:

- a plurality of DTF calculation blocks on N points with there being sent to each block one of the vectors $\hat{\boldsymbol{d}}^{(i)}$ to find at the output of each block a corresponding vector $\hat{\mathbf{D}}^{(i)}$;
- transformation means which receive the vectors $\hat{\mathbf{D}}^{(i)}$ and which perform the transformation represented by a matrix Γ^{-1} if a ZF-BLE equalization is wanted or by a matrix $[\sigma^2 N\mathbf{I}_M + \Gamma]^{-1}$ if an MMSE-BLE is wanted so as to give at their output corresponding U vectors $\mathbf{R}^{(1)},\ldots,\mathbf{R}^{(U)}$, and
- a plurality of IDTF calculation blocks on N points with there being sent to each block one of the vectors $\mathbf{R}^{(1)},\ldots,\mathbf{R}^{(U)}$ to find at the output of each block a corresponding vector $\mathbf{r}$ made up of N elements with said vectors $\mathbf{r}$ being the sought estimation vectors $\mathbf{r}^{(1)},\ldots,\mathbf{r}^{(U)}$.

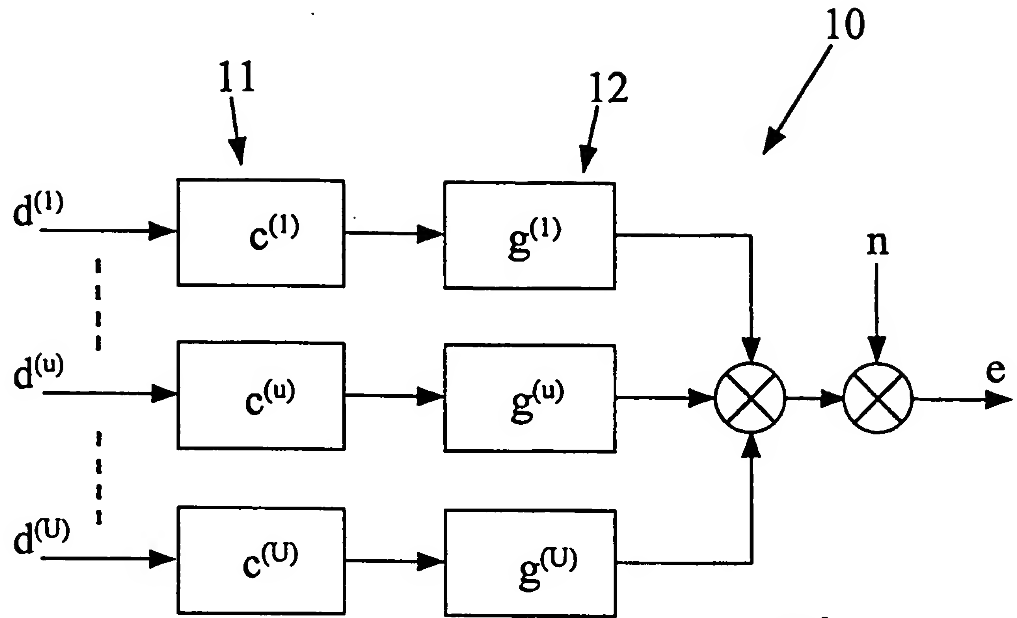
10
11
12
d(1)
c(1)
g(1)
n
d(u)
c(u)
g(u)
e
d(U)
c(U)
g(U)

Fig.1

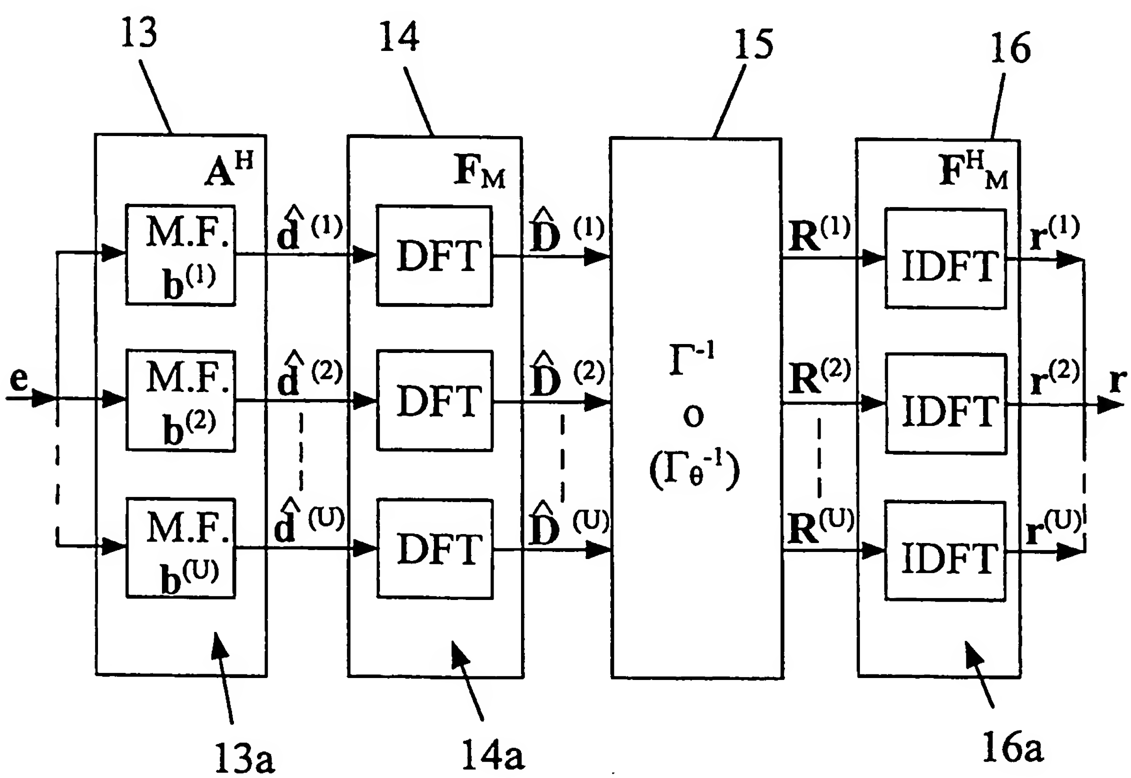
13
14
15
16
A^H
F_M
F^H_M
M.F. b(1)
M.F. b(2)
M.F. b(U)
DFT
DFT
DFT
Γ^-1 o (Γθ^-1)
IDFT
IDFT
IDFT
e
r
13a
14a
16a

Fig.2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/05296

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B1/707

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	BENVENUTO N ET AL: "Joint detection with low computational complexity for hybrid TD-CDMA systems" GATEWAY TO 21ST CENTURY COMMUNICATIONS VILLAGE. VTC 1999-FALL. IEEE VTS 50TH VEHICULAR TECHNOLOGY CONFERENCE (CAT. NO.99CH36324), GATEWAY TO 21ST CENTURY COMMUNICATIONS VILLAGE. VTC 1999-FALL. IEEE VTS 50TH VEHICULAR TECHNOLOGY CONFERENCE, AMSTERDAM,, pages 618-622 vol.1, XP002149179 1999, Piscataway, NJ, USA, IEEE, USA ISBN: 0-7803-5435-4 abstract page 618, column 2, line 10 - line 20 page 621, column 1, line 6 -column 2, line 7; figure 2 --- -/--	1,2

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 October 2000	17/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Ó Donnabháin, E

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter national Application No
PCT/EP 00/05296

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	INKYU LEE ET AL: "A FAST COMPUTATION ALGORITHM FOR THE DECISION FEEDBACK EQUALIZER" IEEE TRANSACTIONS ON COMMUNICATIONS,US,IEEE INC. NEW YORK, vol. 43, no. 11, 1 November 1995 (1995-11-01), pages 2742-2749, XP000536298 ISSN: 0090-6778 abstract page 2742, column 2, line 21 -page 2743, column 1, line 16 page 2744, column 1, line 11 -column 2, line 18	1,2
Y	JUNG P ET AL: "A GENERALIZED VIEW ON MULTICARRIER CDMA MOBILE RADIO SYSTEMS WITH JOINT DETECTION (PART II). EINE VERALLGEMEINERTE DARSTELLUNG VON MOBILFUNKKONZEPTEN MIT MULTITRAEGER-CDMA UND GEMEINSAMER DETEKTION (TEIL II)" FREQUENZ,DE,SCHIELE UND SCHON GMBH. BERLIN, vol. 51, no. 11/12, 1 November 1997 (1997-11-01), pages 270-275, XP000765910 ISSN: 0016-1136 page 271, column 1, line 24 -page 272, column 2, line 12; figures 11,12	1,2
A	KARIMI H R ET AL: "A novel and efficient solution to block-based joint-detection using approximate Cholesky factorization" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS,XX,XX, vol. 3, 1998, pages 1340-1345, XP002112134 abstract	1,2

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Form PCT/ISA/210 (continuation of second sheet) (July 1992)